A Morphology Index for Soil Quality Evaluation of Near-Surface Mineral Horizons

R.B. Grossman, Soil Scientist, National Soil Survey Center, Lincoln, Nebraska

D.S. Harms, Soil Scientist, National Soil Survey Center, Lincoln, Nebraska

C.A. Seybold, Soil Scientist, Soil Quality Institute, Portland, Oregon

M.T. Sucik, Soil Scientist, Soil Quality Team, Akron, Colorado

Introduction

We present a protocol for an index of near surface quality based on pedological morphology. The protocol is based on structure and moist rupture resistance adjusted for crust and for macroscopic surface-connected features. All observations are for field capacity or wetter. Properties are defined in the Soil Survey Manual (Soil Survey Staff, 1993. USDA Hnbk 18. Washington, DC).

The Protocol

The zone examined extends from the mineral soil surface to 30 cm or to a root barrier if above 30 cm. Layers are delimited wherever there is a change in the class of grade, size, or shape of structure, in rupture resistance, or in surface-connected morphological features above 10 cm. At least 50 mm of water must have passed through the zone after tillage and all parts must have been both wet or very moist and slightly moist or dry.

Five classes are provided for each defining feature (5 as the best). The class sets are combined to form 2-digit numbers between 1 and 5 or may be expressed on a 100 base: $Index_{100} = 100 - ((5 - Index_5) \times 25)$.

The four classes of texture to follow with letter designations A through D are used throughout:

A - ≥ 70% sand, < 18% clay　　B - < 70% sand, 0-18% clay　　C - 18 - 40% clay　　D - ≥ 40% clay

Tables 1 and 2 contain the classes for structure and for moist rupture resistance. Moderately moist or wetter is assumed. Following are the rules combining structure and rupture resistance using the previously given classes of texture.

Texture Class	Rule
A	Rupture resistance only
B	Whichever of the two properties that has the higher index
C, D	Weight structure twice rupture resistance except if very friable in which case use rupture resistance alone

The relative importance of structure increases as texture becomes finer because maximum structural expression increases and is more diagnostic of quality.

Table 3 pertains to dry raindrop impact crust, Table 4 to surface-connected macropores, and Table 5 to surface-connected cracks. The macropores must exceed 2 mm diameter at the ground surface and be more than 0.5 mm across to 10 cm depth. Surface-connected cracks must exceed 5 mm across and be present after the near surface has been moderately moist or wetter continuously for at least 1 week. Depth measured by gentle insertion of a blunt wire 2 mm diameter must exceed 10 cm. The higher of the class placements for macropores or for cracks is used.

Table 6 contains illustrative observations for the crust and ground surface. Table 7 contains a hypothetical example of the calculation of the overall index 0-30 cm inclusive of the information in Table 6. The righthand 3 columns in Table 7 give the index based on structure and rupture resistance (SRI), on structure, rupture resistance, and crust (SRCI), and on structure, rupture resistance, crust, and surface-connected features (SRCSI).

Crust placement is based on the dry rupture resistance and the thickness of the reconstituted zone (Table 3) of airdry specimens. In-place morphology is not involved. For each layer, the crust index is subtracted from that for structure and rupture resistance. Negative or zero differences are ignored. Half of positive differences are subtracted from the structure-rupture resistance index. Next the index inclusive of crust is subtracted from the higher of either the macropore or crack indices from Tables 4 and 5. Half of positive differences are added to the structure-rupture resistance-crust index throughout the uppermost 10 cm. The increase cannot exceed 2.0. An overall index 0-30 cm is computed. Average indices weighted by thickness are calculated for three 10 cm thick intervals or for the total thickness divided by 3 if there is a root barrier above 30 cm. Next the indices for the three intervals are weighted 4, 2, and 1 with increasing depth and an overall weighted average computed.

Discussion

As an illustration, Table 8 compares the morphology index for nearby traffic and nontraffic rows within a long term controlled traffic experiment. The indices of 20 and 73 are about the maximum range encountered for the soil as cultivated. Figure 1 contains photographs of the two near surfaces.

Other protocols may be adopted. One would be to combine the lowest index with its depth of occurrence. Suppose the lowest index was 3.0 and it occurs at 10-16 cm. The product of the midpoint of the zone with the lowest index and the index would be 13 x 3 = 39. If 2.0 were the lowest index and the depth 5 cm, the index would be 10. In this approach, the weighting is 1:1 with depth, whereas in the protocol given the weight decreases with depth.

Comments: The first need is to place more emphasis on description of the near surface, particularly for cultivated soils. This is much more important that the manner of reduction of the information. Secondly, reduction of near-surface morphological information to indices should help communication to people outside of pedology. And finally, if soil quality becomes part of federally mandated conservation programs, then it may be advantageous to express near-surface morphology numerically.

Table 1. Soil Quality Classes of Structure While Moderately Moist and Wetter

Class	Criteria †
1	All structures with common or many stress surfaces irrespective of other features, massive, platy with firm or stronger horizontal rupture resistance, all weak structure except granular, moderate very coarse prismatic, all columnar.
2	All structures with few stress surfaces irrespective of other features, weak granular, moderate very coarse and coarse blocky and coarse and medium prismatic, platy with friable horizontal rupture resistance, strong very coarse and coarse blocky, strong medium and coarser prismatic.
3	No stress surfaces, moderate medium blocky and very fine and fine prismatic, platy with very friable horizontal rupture resistance.
4	No stress surfaces, moderate granular, moderate very fine and fine blocky and very fine prismatic, strong fine through medium prismatic.
5	No stress surfaces, strong granular, strong very fine through medium blocky and very fine prismatic.

† If the structure is described as "parting to" use the stronger of the two structures. If intermediate structure classes are described, use intermediate classes here.

Table 2. Soil Quality Classes of Moist Rupture Resistance

Texture Class	Moist Rupture Resistance †				
	Loose	Very Friable	Friable	Firm	Very Firm & Stronger
A	2	3	3	2	1
B	3	4	3	2	1
C	4	5	3	2	1
D	5	5	4	1	1

† For 0-5 cm, if very friable and structure classes 1 or 2, place in class 2. This is done because surficial zones that are massive or have weak structure are prone to erosion.

Table 3. Soil Quality Classes for Crust Based on Thickness of the Reconstituted Zone, and Dry Rupture Resistance Subdivided on Texture Class

Thickness	Dry Rupture Resistance (in Newtons)											
(mm)	Very Weak			Weak			Moderate, Moderately Strong, Strong			Very Strong, Extremely Strong		
	A	B, C	D	A	B, C	D	A	B, C	D	A	B, C	D
< 1	5	5	5	5	5	4	4	4	3	4	3	3
1 - 2	5	5	5	5	4	3	4	3	2	3	2	2
2 - 4	5	5	5	4	3	2	3	2	1	3	2	1
4 - 8	5	5	4	4	3	2	3	2	1	2	1	1
8 - 20	5	5	4	4	3	2	3	2	1	2	1	1
≥ 20	5	4	3	4	2	1	2	1	1	2	1	1

Table 4. Soil Quality Classes for Surface-Connected Macropores

Class	Abundance, Size
5	Many coarse and very coarse
4	Many medium or coarse
3	Common coarse and very coarse
2	Common medium or coarse
1	Few or no medium, coarse, or very coarse

Table 5. Soil Quality Classes for Surface-Connected Cracks

Class	Areal Percent
1	≥ 5
2	2 - 5
3	1 - 2
4	0.5 - 1
5	< 0.5

Table 6. Hypothetical Illustrative Soil Quality Input of Crust and Surface Features

Feature	Observation	Class
Raindrop Impact Crust	Class C Texture 10 mm Thick Moderately Strong	2
Surface-Connected Macropores	Common, Medium and Coarse	4
Surface-Connected Cracks	< 0.5 percent of area	1

Table 7. Illustrative Hypothetical Soil Quality Record

Depth	Horizon	Texture Class	Structure / Rupture Resistance	Indices †		
cm				SRI	SRCI	SRCSI
0 - 1	Crust (Ap_1)	C	Massive, Friable	--	2.0	3.0
1 - 2	Ap_2	C	Moderate Fine Granular, Very Friable	4.3	3.2	3.6
2 - 5	Ap_3	C	Moderate Very Fine Subangular, Very Friable	4.3	3.2	3.6
5 - 10	Ap_4	C	Weak Medium Blocky, Friable	1.7	1.7	2.9
10 - 18	Ap_5	C	Moderate Coarse Blocky, Firm	2.0	2.0	2.0
18 - 24	AB	D	Moderate Medium Blocky, Friable	3.0	2.5	2.5
24 - 30	Bt	D	Strong Very Fine Blocky, Very Friable	5.0	3.5	3.5
0 - 10						3.2
10 - 20						2.1
20 - 30						3.1
0 - 30						2.9 = 48

† SRI - Structure-rupture resistance index; SRCI - Structure-rupture resistance-crust index; SRCSI - Structure-rupture resistance-crust-surface features index.

Table 8. Comparison of the Morphology Index for Traffic and Non-Traffic Interrows in a Long Term Controlled Traffic Experiment † ‡

Depth (cm)	Structure Rupture Resistance Non-Traffic	SRI§	Depth (cm)	Structure Rupture Resistance Traffic	SRI§
0 - 3	Moderate to weak fine granular, very friable	3.7	0 - 3	Strong very coarse platy, friable	1.7
3 - 6	Moderate very fine subangular, very friable	4.3	3 - 18	Massive, firm	1.3
6 - 14	Moderate to strong, fine blocky, friable	4.0	18 - 22	Moderate medium to coarse blocky, firm	2.3
14 - 20	Moderate fine to medium blocky, friable	3.3	22 - 30	Moderate fine blocky, very friable	4.3
20 - 25	Moderate fine blocky, very friable	4.3			
25 - 30	Moderate fine blocky, very friable	4.3			
0 - 10		4.0	0 - 10		1.4
10 - 20		3.6	10 - 20		1.5
20 - 30		4.3	20 - 30		3.9
0 - 30		3.9 = 73	0 - 30		1.8 = 20

† At Rogers Farm, University of Nebraska, located in southeast Lancaster County. The soil is Wymore, an Aquertic Argiudoll, fine, smectitic, mesic. All parts 0-30 cm are fine-silty or fine. Data from 7/19/97.
‡ Ksat by a constant-level borehold device (Amoozegar and Warrick. 1986. Methods of Soil Analysis). Water column 10-25 cm. For traffic 0.040 in hr^{-1} and for non-traffic 2.3 in hr^{-1}.
§ Structure-Rupture Resistance Index. Raindrop-impact crust, macropores, and cracks not present.

Summary

We present a scheme to express near-surface pedological morphology numerically using structure, moist rupture resistance, raindrop impact crust, and surface-connected features (macropores and cracks). Crust and surface-connected features are permitted to override the structure and rupture resistance to a degree. The index gives more weight to the uppermost 10 cm. An important advantage is that a large amount of information is reduced to a single number, which should facilitate increased use of pedological morphology in decision making.

Figure 1

Left from non-traffic interrow (morphology index 73) and right from traffic interrow (morphology index 20) in controlled traffic experiment on Wymore soils.

Scale is 5 x 5 cm.